1. TITLE OF THE THESIS

"Cyanobacterial Species of Durg-Rajnandgaon District with Special Reference to Bioremediation of Heavy Metals"

2. INTRODUCTION

Cyanobacteria, formerly called "Blue-Green Alga" are relatively simple, primitive life forms closely related to bacteria. They are morphologically diverse group of unique photosynthetic organisms of great importance because of their very long existence for well over 3.5 billion years and cosmopolitan distribution in terrestrial, freshwater and marine habitats (Fritsch, 1952; Desikachary, 1959 and Chellapa *et al*, 2004). They are nature's unique gift to mankind, as they possess several innate properties that make them ideal organisms with potential for multifaceted biotechnological applications. As a basic research tool, they are largely known to provide critical insights into the origin of life, photosynthesis, nitrogen fixation and primary and secondary metabolism (Anand, 1998).

During the recent past, studies on Cyanobacteria have emphasized their important role in ecosystem. They grow at any place and in any environment where moisture and sunlight are available. However, they show specific growth pattern in a specific environment and therefore there distribution, ecology, periodicity, qualitative and quantitative occurrence differ widely (Prasad *et al*., 1980; Muthukumar *et al*., 2007; Vijaykumar *et al*., 2007; Saadatnia and Riahi, 2009).

On account of their immense applied biotechnological potentials, they are being explored widely. Recently, Cyanobacteria have gained significance as sources of wholesome food materials, fixed atmospheric nitrogen ((Rao and Burns, 1990 a, b and Valiente *et al.,* 2000), bioplastics, biofuels, fine chemicals, bioactive substances ((Subramanian and Shanmugasundaram, 1986 and Kumar *et al.,* 2003), fine chemicals like lipids, pigments, enzymes, polysaccharides (Pal, 2008), and other novel biologically active compounds involve in remediation of polluted environments (Torresdey *et al*., 1998; Kumar *et al.*, 2011 and Sri Kumaran *et al*., 2011). Active research in the field of Cyanobacterial bioremediation technology has opened up vast opportunities, whereby, these microbes could be used for eliminating human sufferings through pollution free environment (Vijaykumar *et al*., 2012).

A wide variety of both inorganic and organic pollutants and heavy metals like Cd, Cr, Zn, Hg, As, Pb and Cu are present in effluentas from domestic activites, industrial effluents and agricultural discharges which eventually mix in the surrounding and make them polluted (Lovley, 1994;; Yoshida *et al*., 2006; Das *et al*., 2007; Sturat *et al.,* 2009; Ray and Ray, 2009 and Sharma, 1975). Their remediation depends on the biogeochemistry of the water bodies or soils impacted by industries discharging effluents in to them (Nies, 1999 and Ray *et al.*, 2009).

Bioremediation is like an option that offers the possibility to destroy or render contaminants using natural biological activities (Gupta, 2013). Microorganism, including Cyanobacteria, due to their large surface to volume ratio and high metabolic activities are important vectors in introducing heavy metals and radionuclide pollutants in to food webs (Torresdey *et al*., 1998; Atlas and Bartha, 2007 and Rajendran *et al.*, 2003). The microbes perform the function of bioremediation are known as bioremediators. These bioremediators use the contaminants as nutrient or energy sources (Agarwal, 1998; Yoshida *et al*., 2005; Tang *et al*., 2007) and enzymatically attack the pollutants and convert them to harmless products.

Durg- Rajnangoan region of Chhattisgarh state is blessed with abundant water bodies and ample rain fall. The area is largely covered by agricultural lands and some agro based industries. Due to a large steel plant (Bhilai Steel Plant), some ancillary industries and power plant are also placed here which release their effluents in the surrounding water bodies. Preliminary studies conducted on Cyanobacterial species reveals that there is a great possibility of occurrence of novel species in the area and there are seasonal variations too (Shrivastava *et al*., 2009 and Kulkarni and Gupta, Communicated). However systematic studies have not yet done. In view of the great biotechnological potential of Cyanobacteria in remediation of pollutant heavy metals and the abundance of their biomass in the indigenous environment, an extensive study has been proposed on their qualitative and quantitative distribution and on their bioremediation potential so as to find the prospect of using them as bioremediator in pollution control systems.

3. REVIEW OF THE WORK ALREADY DONE IN THE FIELD

Cyanobacteria show wide ecological tolerance and they occur in almost every conceivable habitat on earth. They are found naturally as planktonic forms in both freshwater and marine ecosystems and also as gelatinous mat like growth on shaded soil, rocks, mud, wood and some living organisms. Tropical conditions such as those in India provide favorable environment for the luxuriant growth of these organisms in the natural ecosystems. Diversity studies for

exploiting their innate potential have been done by many in various habitats. Misra *et al*. (2005) have worked on the algal flora of various parts of Nothern India. Tiwari *et al*. (2006) indicated that high temperature is favorable for the growth of cyanophycean texa. Johnson *et al*. (2006) studied the algal flora of Banjara and Nadimi lakes and reported that the lakes were euthropic and dominated by cyanophycean and bacillariophycean members. Muthukumar *et al*. (2007) observed Cyanobacterial biodiversity in addition, certain physioco-chemical parameters of pond water from Thanjavar, Tamilnadu (India). Auti *et al*. (2010) worked on algal diversity of Pravara River in Ahmednagar district (Maharashtra). Sanap *et al*. (2012) noticed tremendous variation in algal diversity, its population and percentage composition at Godawari River, Nashik. They indicated that change in water flow; transparency and temperature affected the growth and abundance of cynophyceae in river water.

Inspite of the fact that the Cyanobacteria are ubiquitous; their population dynamics are often influenced by the available nutrients and the physico-chemical conditions of the ecosystem. This group of photosynthetic prokaryotes is structurally simple, but it is physiologically diverse and well adapted to environmental extreme conditions, especially nutrient deficiency and excesses (Kiran and Thanasekaran, 2012). The Cyanobacteria have developed an array of biochemical and ecological mechanisms to access the changes around and ability to use or convert them into useful forms. Nandkar *et al*. (1983) reported that algae like diatoms, *Spirogyara, Oscillatoria spp.* play an important role in the purification of polluted water due to their high rate of oxygen liberation during photosynthesis. Singh *et al*. (2007) observed Cyanobacterial spp. like *Oscillatoria, Calothrix, Tylopothrix* have been eliminated from the ecosystem by continuous use of pesticides. Rao *et al*. (2007) studied the effect of malathion on akinete formation, heterocyst differentiation on Cyanobacteria.

A wide mixture of heavy metals like Cd, Cr, Hg, As, Pb and Cu are present in water bodies due to domestic activities and industrial and agricultural discharges. Heavy-metal pollution represents an important environmental problem due to the toxic effects of metals, and their accumulation throughout the food chain leads to serious ecological and health problems (Malik, 2004). Bioremediation has been introduced to describe the process of using biological agents to remove toxic waste from environment. Bioremediation has been used at a number of sites worldwide, with varying degrees of success. Cyanobacterial Biodiversity and its application for the treatment of domestic and industrial effluents have received more attention during the recent

years. Bioremediation, both in situ and ex situ have also strong scientific growth. Nies *et al*. (1999) described the metal resistance system in microorganisms. Rajendran *et al.* (2003) indicated the metal-microbe interaction and their application for metal accumulation, detoxification and the potentials of microbes in metal remediation. Yoshida *et al.* (2005) isolated heavy metal resistant unicellular algae *Chorella sorokiniana* and indicated it potentially useful for phytoremediation of heavy metals. They observed that Cyanobacteria were the most sensitive organisms for Cd^{2+} toxicity and reported that glucose, sucrose, maltose, galactose and soluble starch as sole carbon support the growth of Cyanobacteria. Das *et al*. (2007) have done biosorption studies on algae, fungi, bacteria and yeast and concluded an economical means of treating effluents. Ray *et al*. (2009) discussed the potential of bioremediation of metal toxicity and its impact on environment. Kumar *et al*. (2011) concluded that bioremediation technology offers an efficient and cost effective way to treat contaminated ground water and soil. Vijayakumar (2012) indicated that Cyanobacteria have the capacity to utilize nitrogenous compounds, ammonia and phosphates; in addition, they accumulate metal ions such as Cr, Co, Cu and Zn very effectively. He observed that immobilized Cyanobacteria have greater potential than free cells. Srivastava *et al*. (2013) demonstrate the laboratory scale bioremediation of the Yamuna water using Effective Microbes (EM) Technology. The result showed that if good, stable and effective waste water treatment is achieved, then waste water reuse becomes increasingly safe.

The biological mechanism in Cyanobacterial cells in response to heavy metals have been demonstrated in some of the studies. Das *et al*. (2007) reported the metal resistance in Cyanobacterial species by the mechanism of biosorption. The metal ions are adsorbed to the surface of cell by metal binding mechanisms like coordination, complexation, ion exchange, physical adsorption or inorganic microprecipitation and then penetrate the cell membrane and enter in to the cells. Many Cyanobacteria produce Extracellular Polymeric Substances (EPS). EPS of microbial origin are a complex mixture of biopolymers comprising polysaccharides, proteins, nucleic acids, uronic acids, humic substances, lipids etc. The association of EPS to the cell surface as sheaths, capsules and slimes has been reported by Phillips and Vincenzini (2003) and Pereira *et al*. (2009). Pal *et al*. (2008) and Pereira *et al*. (2011) reported some Cyanobacterial species which produce Extracellular Polymeic Substances (EPS) and observed that production of EPS is greatly enhanced under so-called stressful cultural conditions imposed by nutrient

limitations and toxic substances including heavy metals. The ability of EPS producing Cyanobacteria to remove heavey metals from aquous solution has been studied by Phillips *et al*. (2011). Torresdey *et al.* (1998) concluded that some proteins may also act as defense mechanisms employed by the organism by binding metal ions intracellularly.

4. OBJECTIVES

1. To isolate Cyanobacterial species from different water bodies and agricultural fields of Durg and Rajnandgaon district.
2. To find out heavy metal resistance in available Cyanobacteria of study area.
3. To correlate bioremediation ability of Cyanobacteria and physibility study for wide applications.

5. NOTEWORTHY CONTRIBUTION IN THE FIELD OF PROPOSED WORK

Cyanobacterial populations from chemical, distillery and oil refinery industrial effluents have been isolated and identified by Subramaniyan *et al.* (2012).The diversity observed has been correlated with physico-chemical characteristics of the effluents. Altogether 63 species of cyanobacteria were recorded from study sites. Among the effluents, distilleries contained the maximum number species (63) followed by chemical (52) and oil refinery (43). Except oil refinery effluent, others recorded heterocystous cyanobacteria. Totally 34 common species were observed in all the effluents. *Oscillateria* with 14 species was the dominant genus followed by *Lyngbya* (7), *Phormidium* (6). The results of this study reveals that higher amount of phosphates and nitrates, with sufficient amount of oxidizable organic matter and limited DO contents played a vital role in their distributional pattern.

Okmen et al. (2011) investigated the effects of various zinc concentrations (2.5 mg/l to 80 mg/l) on biomass, chlorophyll a, total carbohydrate and total protein contents of 10 cyanobacterial species by spectrophotometric method. Zinc is toxic to these organisms causing severe inhibition of such physiological process as growth, chlorophyll a, carbohydrate and protein contents at concentrations less than 10 mg/l. *Anabaena* sp. GO1 and *Gloeothece* sp. GO9 were partly stimulated at lower zinc concentration (2.5 mg/l). In the high concentrations of zinc is more than 10 mg/L, biomass and other parameters of all cultures were completely reduced, except *Anabaena* sp. GO2 species.

Sri Kumaran *et al.* (2011) studied on cyanobacterial isolates from the contaminated water and suggested that the study may be helpful to bioremediation research in future. Metal adsorption

studies were done by the dilution method at varying concentrations (10 to 1000µgL-1) of Ni2+, Cd2+, Fe2+, Pb2+ and Zn2+. *Nostoc* species showed high resistance among all other isolates and used for further studies. During the experiment 95.4% of Cd, 97.7% of Fe, 99.6% of Pb, 88.23% of Ni and 75.3% of Zn was removed by the *Nostoc* species.

6. PROPOSED METHADOLOGY

Selection of sampling sites – Survey for selection of sampling site from Durg and Rajnandgaon District will be done on the basis of type and size of water body and agricultural field. Water / Soil samples will be randomly collected ones in three months from each sampling site. Special emphasis will be given to the sites receiving domestic, agricultural and industrial effluents.

Physico-chemical characterization of water and soil samples – The collected samples will be processed for determination of colour, odour, pH, DO, EC, BOD, COD, Free Co_2, TDS, Chloride, Nitrate and Phosphate by using standard methods like APHA (1985).

Isolation of Cyanobacterial species and selection of best growth media – Microscopic examination of collected samples will be initially done to assess the diversity. Collected samples will be transfered to suitable culture medium like BG-11 medium for isolation and incubated for about two weeks in culture room at 25 ± 1^{o}C under controlled continuous illumination. Standard plating / streaking techniques will be used for purification of cyanobacterial strains (Nayak and Prasanna, 2007). The plates will be examined and the best colonies will be selected, picked up and re-streaked to new agar plates to obtain mono algal cultures. Identification of individual isolate will be done with the help of relevant literatures and monographs provided by Desikachary (1959); Prescott (1962) and Kamat (1962). Pure monocultures will be further cultured using different media like BG-11 medium, SE (Soil Extract) medium, Chu 10 medium, Allen and Arnons medium, Pringsheim's to select the best growth medium. Growth will be compared by OD_{50} and recovery of biomass (Yoshida *et al.*, 2005).

Isolation of heavy metals resistant species of Cyanobacterial – The mono cultures of different species will be screened for isolation of heavy metal resistant strain. Sterilized solutions of different heavy metals like Arsenic, Copper, Mercury and Lead will be aspectially supplemented with suitable culture medium. Resistant strain will be selected on the basis of growth OD_{550} and dry biomass recovered and compared with control (Yoshida *et al.*, 2006).

Determination of total chlorophyll, total carbohydrate and total protein contents – Total chlorophyll content will be calculated according to Jeffrey's equation (Jeffery, 1976). Total carbohydrate contents will be measured by the phenol-sulphuric acid method (Dubois *et al*., 1956) and total protein contents will be measured by method given by Leitao *et al*. (2005) using BCA as standard.

Determination of Minimum Inhibitory Concentration for heavy metals – The minimum inhibitory concentration was defined as the lowest concentration of metal that completely inhibit the growth of any species. Different heavy metal solutions will be added to best suited culture medium under best suited cultural conditions maintaining the controls (Yoshida *et al*., 2005). The MIC of the metals for each isolate was determined by the plate dilution method as adopted by Sri Kumaran *et al*. (2011).

Heavy metal uptake studies – Metal binding properties of pure isolates in terms of effect of pH, time dependency and metal binding capacity of biomass and compared over control for loss during incubation. Uptake/ Desorption of adsorbed metal in terms of residual heavy metals will be analyzed by AAS (Torresdey *et al.,* 1998, Bala Kiran and K. Thanasekaran, 2011).

Potential for bioremediation – Heavy metal resistant pure isolates will be screened for their potential for reversing plant growth inhibition caused by heavy metals in terms of reversion of seed germination inhibition and shoot growth inhibition (Yoshida *et al*., 2006).

Analysis of data – Five replicates will be maintained throughout the studies and the observations recorded will be analyzed for Relative abundance, Diversity Index and Similarity coefficient. Data will also be analyzed by suitable statistical methods (Muthukumar *et al*., 2007).

7. EXPECTED OUTCOME OF THE PROPOSED WORK

1. The Cyanobacterial isolates of the study sites will give inference on diversity of unexplored / under explored habitats.
2. The physico-chemical characterization of the study samples will help in determining the supportive or affective conditions for growth of the species.
3. Possibility of heavy metal resistance of isolates may lead to selection of a judicious species or consortium of metal-resistant cells, which may ensure better removal of toxic contaminants from environment.

4. Applicability of growing Cyanobacterial cells for metal removal and the efforts directed towards process development may make the options technically viable for the comprehensive treatment of metal-rich effluents.

8. BIBLIOGRAPGY

Agrawal, S.K., 1998. Environmental Biotechnology, 11th edn., APH Publishing Corporation, New Delhi, India, 267-289.

Anand, N., 1998. Indian Fresh Water Microalgae, B. Singh and M. P. Singh Dehradun, India., 94.

APHA, 1975. Standard methods for the examination of water and waste water (14th edn.), American Public Health Association, Washingtion, D.C.

Atlas and Bartha. 2007. Microbial Ecology: Fundamentals and Applications. Fourth Edition. Pearson Education.

Auti, B.K., Pingle, S.D. 2010. Soil blue-green algal diversity from Arable Domain of Pravara area, Ahmednagar. Advances in Plant Sciences, An International Journal, 23: 41-43.

Bala Kiran and K. Thanasekaran 2011.Metal tolerance of an indigenous cyanobacterial strain, Lyngbya putealis. International Biodeterioration & Biodegradation 65: 1128- 1132.

Bender, J., Susana, R.E., Ekanmesang, U.P. and Phillips P. 1994. Characterization of metal binding biofloculants produced by the Cyanobacterial component of mixed microbial maps. Applied and Environmental Microbiology, 60 (7): 2311-2315.

Chellappa, S.L., Marinho, I.R. and Chellappa, N.T. 2004. Fresh water phytoplankton assemblage and the bloom of toxic cyanophyceae of Campo Grande Reservoir of Rio Crande do Norte state of Brazil, Indian Hydrobiology 7: 151-171.

Das, N., Vimala, R. and Karthika, P. 2008. Biosorption of heavy metals- An overview. Indian Journal of Biotechnology, 7: 159-169.

Das, S.K., Samad, L.K., Ramanajun, P., Adhikary, S.P. 2007. Freshwater algae of Meghalaya. The Journal of The Indian Botanical Society, 86: 3-4.

De Philippis, R. and Vinienzini, M., 2003. Outremost polysaccharide investements of cyanobacteria: nature, significance and possible applications. Recent Res Dev. Microbiology 7: 13-22.

Desikachary, T. V., 1959. Cyanophyta. ICAR, New Delhi.

Fritsch, F.E., 1935. The Structure and Reproduction of Algae. 1 and 2. Cambridge Uni. Press, Lond.

Gadd, G.M. 2004. Microbial influence on metal mobility and application for bioremediation. Geoderma 122: 109-119.

Gupta, R. and Mahapatra H., 2003. Microbial biomass: An economical alternative for removal of heavy metals from waste water. Indian Journal for Environmental Biology 41: 945-966.

Johnson, M.E.C. 2006. Algal flora of Banjara and Nadimi Lakes. The Journal of The Indian Botanical Society, 85 (1-4): 103-106.

Kamat, N.D., 1962. The Cyanophyaceae and Chlorophyaceae of Panhala. J. Uni., Bombay., 3 (3-5): 22-31.

Kumar, A., Bisht, B.S., Joshi, V.D., Dhewa T. 2011. Review on bioremediation of polluted environment: A Management Tool. International Journal of Environmental Sciences,1 (6): 1079-1093.

Kumar, K., Lakshmanan, A. and Kannaiyan, 5., 2003. Bioregulatory and therapeutic effects of Blue green algae. *Indian J. Microbiol.,* 43 (1): 9-16.

Lovely, D.R. 1994. Bioremediation of organic and metal contaminants with dissimilatory metal reduction. Journal of Industrial Microbiology, 85.

Misra, P.K. and Srivastava, A.K. 2005. Fresh water cyanophycean algae from North-Eastern Uttarpradash, India. The Journal of The Indian Botanical Sosiety, 84: 67-75.

Muthukumar, C., Muralitharan, G., Vijyakumar, R., Panneerselvam, A. and Thajuddin, N. 2007. Cyanobacterial biodiversity from different freshwater ponds of Thanjavur, Tamilnadu (India). Acta Botanica Malacitana, 32: 17-25.

Nandkar, P.B. and Marathe, K.V. 1983. Eastimation of the oxygen produced by dominant algae of six polluted streams. The Journal of The Indian Botanical Society, 62: 245-251.

Nayak, S. and Prasanna, R. 2007. Soil pH and its role in cyanobacterial abundance and diversity in rice field soils. Applied Ecology and Environmental Research. 5 (2): 103-113.

Nies, D.H. 1999. Microbial heavy metal resistance. Applied Microbiology Biotechnology, 51: 730-750.

Okmen Gulten , Bozanta Ender , Ugur Aysel and Ceyhan Nur 2011. Zinc Effect on chlorophyll a, Total Carbohydrate, Total Protein Contents and Biomass of Cyanobacterial Species. Journal of Applied Biological Sciences 5 (2): 67-73.

Pal, A., Paul, A.K. 2008. Microbial extracellular polymeric substances: central elements in heavy metal bioremediation. Indian J. Microbiol., 48: 49-64.

Pereira, S., Micheletti E., Zille, A., Santos, A., Pedro, M.D., Tamagnini, P. and De Phillips, R. 2011. Using extracellular polymeric substances producing Cyanobacteria for the bioremediation of heavy metals: do cations complete for the EPS functional groups and also accumulate inside the cell?. Microbiology, 157: 451-458.

Prasad, B.N. and Saxena, M. 1980. Ecological studies of Blue-green algae in River Gomti. Indian J. Environ. Hlth. 22 (2): 151-168.

Prescott, G.W., 1962. Algae of the Western great lakes area. Pub Cranbook. Institute of Science Bullenton. 30

Rajendran, P., Muthukrishan, J. and Gunasekaran, P. 2003. Microbes in heavy metal remediation. Indian Journal of Experimental Biology, 41: 935-944.

Rao, B., Venkateshwarlu, M., Asheervanddham, T., Rao. Ch. 2007. Response of Cyanobacteria to malathion. Advances in Plant Sciences, An International Journal, 20: 251-253.

Rao, D.C.N., Burns, R.G. 1990a. The effect of surface growth of blue-green algae and bryophytes on some microbiological, biochemical and physical soil properties. Biol. Fertil. Soils. 9: 239-244.

Rao, D.C.N., Burns, R.G. 1990. Use of blue-green algae and bryophytes biomass as a source of nitrogen for oil-seed rape. Biol. Fertil. Soils. 10: 61-64.

Ray, S. and Ray, M.K. 2009. Bioremediation of heavy metal toxicity with special reference to chromium. *Al Ameen Med Sci. 2: 57-63.*

Saadatnia, H. and Riahi H. Cyanobacteria from paddy fields in Iran as a biofertilizer in rice plants. 2009. Plant Soil Environ., *55* (5): 207–212.

Sanap, R.R., Pingle, S.D. and Gore, A.B. 2012. Algal population and percentage composition of different alga groups of Godavari River at Nashik (M.S.), India. Advances in Plant Sciences, An International Journal, 25.

Sanap, R.R., Pingle, S.D. 2011. Diversity and distribution pattern of cyanophyaceae with respect to physico-chemical parameters of Godavari River at Nashik (M.S.), India. Advances in Plant Sciences, An International Journal, 24: 365-370.

Sharma, P.D., 1975. Ecology and Environmental. First Edition, Rastogi Publication. 351-368.

Shrivastava, A.K., Shrivastava, D.K., Sahu, T.; 2009. Biodiversity of Cyanobacteria and its

distributional pattern in different habitats of Durg district in Chhattishgarh state. National Journal of Life Science, 61: 229-235.

Singh, D.P., Khattar, J.I.S., Singh, Y. 2007. Effect of pesticide on the distribution pattern of Cyanobacteria in a rice field ecosystem. The Journal of The Indian Botanical Society, 86 (3-4): 163-166.

Sri Kumaran N., Sundaramanicam A. and Bragadeeswaran S. 2011. Adsorption Studies on Heavy Metals by Isolated Cyanobacterial Strain (*Nostoc* sp.) From Uppanar Estuarine Water, Southeast Coast of INDIA Journal of Applied Sciences Research, 7 (11): 1609-1615.

Srivastava, J.N., Singh, A., Verma, S., Raghav, N. 2013. Laboratory scale bioremediation of the Yamuna water using Effective Microbes (EM) Technology. Advances in Plant Sciences, An International Journal, 26: 21-23.

Stuart, R.K., Dupond, C.L., Johnson, D.A., Paulsen, I.T. and Palenik, B. 2009. Costal strains of marine *synechococcus spp.* Exhibit increased tolerance to copper shock and a distinctive transcriptional response relative to these of open ocean strains. Appl Environ Microbiol. 75: 5047-5057.

Subramanian, G. and Shanmugasundaram, S., 1986. Sewage utilization and wall recycling by cyanobacteria. Indian J. Environ. Hlth. 28: 250-253.

Subramaniyan Vijayakumar, Savarimuthu Jeyachandren and Chocckaya Manoharan 2012. Studies on cyanobacterial population in industrial effluents. J. Algal Biomass Utilization, 3 (1): 39-45.

Tambe, D.B. and Pingle, S.D. 2012. Hydrobiological studies of Wilsm Dam (Bhandardara) Tal. Akole, Dist. Ahmednagar (M.S.), India. Advances in Plant Sciences, An International Journal, 25.

Tang, C.Y., Criddle, Q.S. Fu Cs, Leckie, Jo. 2007. Effect of flux (transmembrane pressure) and membranes treating perfluorooctance sulfonate containing waste water. Jou. Environ. Sci. Tech. 41: 2008-2014.

Torresedy, J.L., Arenas, J.L., Francisco N.M.C., Tiemann, K.J., Webb, R. 1998. Ability of immobilized Cyanobacteria to remove metal ions from solutions and demonstration of the presence of metallothionein genes in various strains. Journal of Hazardous Substance Research, 1.

Valiente, F., Ucha, E., Quesada, A., Leganes, F., Carreres, R. 2000. Contribution of N_2 fixing cyanobacteria to rice production availability of nitrogen from ^{15}N- labeled cyanobacteria and ammonium sulphate to rice. Plant Soil. 221 (1): 107-112.

Yoshida, N., Lkeda, R., Okuno, T. 2005. Identification and characterization of heavy metal-resistant unicellular algae isolated from soil and its potential for phytoremediation. Bioresource Technology 97: 1843-1849.

9. LIST OF PUBLISHED PAPERS OF THE CANDIDATE

1. *In vitro* multiplication of sugarcane *(Saccharum officinarum)*. Research Front. Peer reviewed Journal of Multiple Science, Arts and Commerce. Vol. II: 2012.

2. Screening of Cyanobacterial species from indigenous pond for Antifungal activity against Plant Pathogenic Fungi (Communicated).

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